CONCRETE PAVEMENT

Inspector's Manual

6

PORTLAND CEMENT ASSOCIATION

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Inspector's Manual

The activities of the Portland Cement Association, a national organization, are limited to scientific research, the development of new or improved products and methods, technical service, promotion and educational effort (including safety work), and are primarily designed to improve and extend the uses of portland cement and concrete. The manifold program of the Association and its varied services to cement users are made possible by the financial support of over 65 member companies in the United States and Canada, engaged in the manufacture and sale of a very large proportion of all portland cement used in these two countries. A current list of member companies will be furnished on request.

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TABLE OF CONTENTS

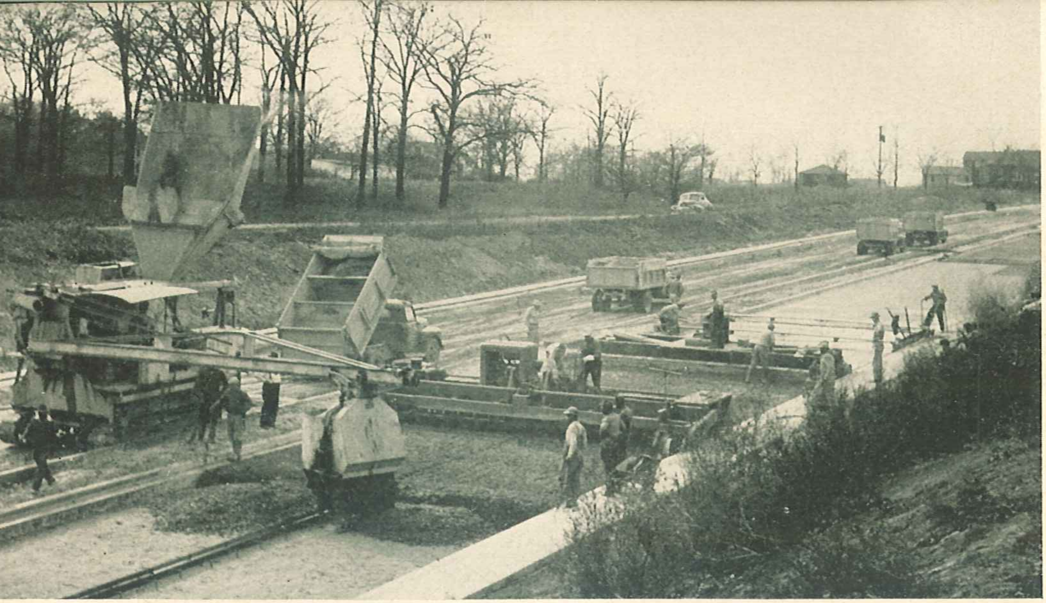
How you can be a SUCCESSFUL PAVEMENT INSPECTOR

As a pavement inspector the responsibility for obtaining a quality job rests largely with you. Yours is not a position to be taken lightly, but one which involves conscientious adherence to certain standards if a quality job is to result.

Know the Specifications Thoroughly. Know the reason for each requirement. Only if you know the reason for each specification requirement, will you be able to use good judgment.

Follow the Specifications Faithfully. You did not write the specifications. The man who did may have had good reasons for inserting provisions which you do not think necessary or advisable. Discuss these provisions privately with your superior if you wish. But, until he has approved a change, see that the written specifications are followed.

Be Consistent in Your Inspection. Insist upon specification results from start to finish. Leave nothing to chance. A wrong method is more easily corrected the first time it is practiced than after it becomes a habit. A reputation for being slack is quickly attained, but difficult to



The inspector's time will be fully occupied if he keeps his eye on the many operations of modern paving.

overcome. A reputation for severity and unreasonableness will breed contempt for an inspector's instructions.

Yours Is a Full-time, Man-sized Job. The first and last work of the day are most likely of all to be defective and to require your full attention. Be on hand when work starts in the morning and when it ends in the evening. Let nothing occur during the day without your knowledge.

Contact Only Necessary Individuals. Instructions and suggestions should be given to foremen, superintendent or contractor only. However, such minor items needing corrections as form alignment, local high subgrade, etc. may be called to the attention of the particular workmen responsible.

Don't Argue. Base your decisions on judgment that reflects coolness, fairness, impartiality, and a thorough knowledge of the work at hand. If a decision is questioned, don't let that weaken your conviction, but signify your willingness to refer to your superiors for further interpretation.

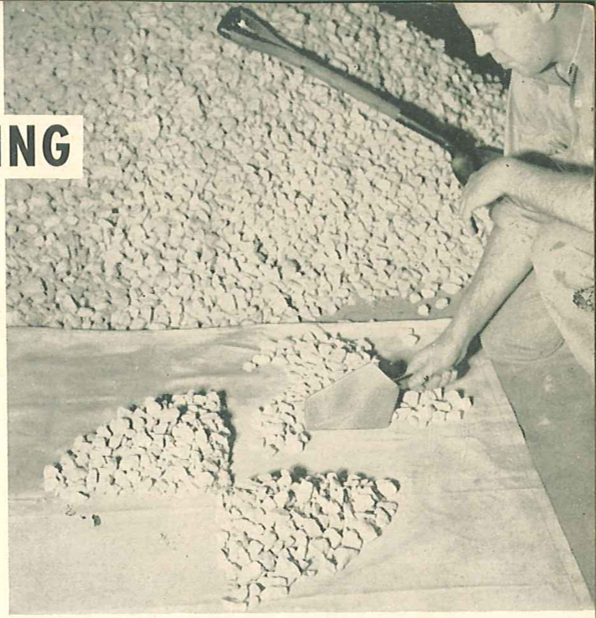
Be Courteous. Be friendly with everyone on the job; be familiar with no one. Familiarity dulls the edge of an inspector's authority. Do not waste foreman's or workmen's time by carrying on unnecessary conversation with them.

Aid the contractor at every opportunity so long as the specifications are not violated, or the quality of the work impaired.

Be courteous to visitors. Future paving depends upon public good will. Do not prejudice the public against road improvement by flippant answers to what may seem foolish questions.

Do not try to magnify your own importance by telling outsiders of the errors you have corrected. The quality of the completed pavement will measure your ability and will be your strongest testimonial.

SAMPLING AND TESTING AGGREGATES



The correct procedure for each sampling and testing operation should be followed carefully.

In general, laboratory tests made before the job is started determine the suitability of materials taken from available sources of supply. But these precautions do not relieve the inspector of responsibility for the quality of the aggregates. It is his duty to see that the materials delivered on the job meet the specifications. Specifications for aggregates provide for a reasonably wide standard of acceptability, but some materials cannot satisfy these requirements. Certain easily conducted field tests will provide a fairly reliable standard of comparison. If the quality of the material is still in doubt, a sample should be sent to the laboratory.

When sampling materials for field or laboratory tests, care must be taken to obtain representative samples. The size of a sample will, of course, depend on the nature of the material and on the scope of the tests to be made. Generally a laboratory sample of fine aggregate should contain not less than 50 lb. and a sample of coarse aggregate not less than 100 lb. The sample should be taken from a selected sample four times larger than the laboratory sample and reduced by quartering, i.e., by thoroughly mixing the material, dividing it into four parts and eliminating the diagonal quarters. This operation is repeated to reduce the sample to the desired size.

In sampling the open face of a pit, the best method is to scoop vertical troughs at equal intervals along the face, placing the material taken from each trough on a canvas and quartering it down to the desired size.

When samples are taken from loaded cars it is necessary to do a considerable amount of digging to obtain a representative sample. A good method is to dig a hole two or three feet deep at several points in the car and, starting at the bottom of each hole, drag the point of the shovel up the side. The samples thus taken from each hole should then be mixed and the composite sample quartered down to the desired size.

It is important that fine and coarse aggregate be well graded in size. An excess of fine material passing the 100-mesh sieve gives rise to difficulties. More mixing water is required; the strength of the resulting concrete is reduced, and pavement surface texture is affected.

On the other hand, sand predominating in coarse particles produces harsh concrete. Size segregation of the coarse aggregate makes it difficult to control the workability, and improperly graded aggregates will not produce economical concrete. Frequent sieve analyses are necessary to control this important requirement in aggregate selection.

An excess of silt or the presence of organic matter in fine aggregates will reduce the strength of the concrete. Silt

also tends to cause scaling. Weak, friable or laminated materials are undesirable, and shale is especially to be avoided.

The inspector should be prepared to make a few simple field tests which will determine, with reasonable accuracy, the quality of concrete aggregates. Among these the sieve analysis, the tests for shale, for organic impurities and for volume of silt are the most common, while the weight per cu.ft. is frequently desired. To make these tests, he will need a set of laboratory sieves, a scale of balance sensitive to 0.1 lb. and weighing up to 60 lb., a $\frac{5}{8}$-in. round rod pointed like a rifle bullet, a $\frac{1}{2}$-cu.ft. box, several 12-oz. graduated prescription bottles, $\frac{1}{2}$ lb. of sodium hydroxide and about 5 lb. of zinc chloride.

The sieve analysis should be made by drying a sample of the aggregate to constant weight, weighing it carefully, and passing the material through the various sized sieves, beginning with the largest sized openings. The sieving operation should be conducted by means of a lateral and vertical motion of the sieve, accompanied by a jarring action. In no case should fragments be turned or manipulated through the sieve by hand. The percentage by weight of the total sample which is finer than each of the sieves can then be computed.

Visual examination of coarse aggregate will often show soft or laminated pieces or chert.

The amount of shale in coarse aggregate can be determined by visual inspection or by immersing the aggregate in a liquid of such specific gravity that the shale and other light particles will float, while the good aggregate will sink. A saturated solution of zinc chloride at a temperature of 78 deg. F. will have a specific gravity of 1.95. Any liquid with that specific gravity will serve. A portion of the sample, dried to constant weight is placed in a container partly filled with liquid and agitated five times. The lighter particles are skimmed off, liquid and pebbles are separated and the operation is repeated until the shale has been removed from the entire sample, which it then washed, dried and weighed.

Organic impurities in sand are discovered by the colorimetric test. The 3 per cent solution of sodium hydroxide required for this test may be made by dissolving 1 oz. of sodium hydroxide crystals in 32 oz. of water.

Fill a 12-oz. graduated prescription bottle to the $4\frac{1}{2}$-oz. mark with the sand to be tested. Add a 3 per cent solution of sodium hydroxide until the sand and solution, after shaking, amount to 7 oz. Shake thoroughly and let stand 24 hours. If the liquid above the sand is clear or has a light yellow color, there is not sufficient organic matter to injure concrete. If it is light brown or darker, the sand should be subjected to laboratory tests before it is accepted.

The silt determination is made by placing 5 oz. of sand in its damp, field condition in one of the 12-oz. graduated bottles, with a sufficient amount of water to fill the bottle to the 10-oz. mark. It should be thoroughly shaken and allowed to stand an hour or so until the water is practically clear. The silt will settle on top of the sand. The line between it and the sand is usually plainly visible and the volume of each may be measured and the percentage of silt obtained. If the wet volume of the silt is more than 7 per cent of the total volume of wet aggregate, approval of the fine aggregate should be withheld until laboratory tests can be made or some other source of fine aggregate selected.

If slag is to be used, the weight per cu.ft. is one of the criterions of quality. A cubic foot is measured by filling the $\frac{1}{2}$-cu.ft. box and rodding the slag in 4-in. layers. The usual specification requirement is that the slag shall weigh not less than 70 lb. per cu.ft.

AT THE PROPORTIONING PLANT

THE uniform strength and the surface of the finished pavement depend to a large extent upon uniformly proportioned batches. These cannot be obtained unless the plant inspector has diligently carried out the instructions of the proportioning engineer.

The proportioning engineer's job is to proportion the materials according to specification and maintain, as nearly as possible, a constant condition of workability and quality in the resulting concrete. The two principal sources of difficulties in the task of maintaining the concrete at a constant consistency are segregated coarse aggregate and varying moisture content of the aggregates.

The plant inspector's first duty when starting a job is to see that the site selected for aggregate piles is cleaned of all weeds and rubbish. The ground should be leveled and rolled if possible before the storage piles are started.

Separation of the different sized particles of aggregates may be largely prevented by building the base of the storage pile to its full diameter, then putting on successive layers three or four feet in depth, instead of building the pile as a cone, allowing the larger stones to roll to the bottom.

Coarse aggregate should also be removed from the stockpile in layers or segregation of the remaining material will result. If the stockpiles are placed on the ground, the material in contact with the soil will likely be dirty. See that it doesn't get into the batching plant.

It is common practice to measure the aggregates for each batch by weight. As soon as the bins are erected check the weighing batches with standard test weights. A set of ten standard 50-lb. test weights is usually used.

Any variation of the scale reading from the true weight is applied as a correction factor when setting the scale to measure aggregates. Specifications usually establish a tolerance of about 0.5 per cent of the net load.

The right amount of portland cement must go into each batch. Workmen should have the sacks of cement for each batch in separate piles in the car door or on the loading platform if bag cement is being used. When bulk cement is used, the weighing equipment should be checked in the manner previously described for aggregate batchers. The inspector should know the total weight of cement used at the end of each day's run, and then compare this with the amount of cement which should have been used.

Cement should be covered while in transit to the mixer, otherwise part of it may blow away. If it is carried in a separate compartment, the compartment should have a cover. If sand from the batch is used for covering the cement long delays in transit must be avoided if cement spoilage is to be avoided. Cement must be protected from moisture while in transit as well as storage.

If the variation in moisture content of the aggregates is known before the materials are used there is no difficulty in maintaining uniform consistency of the concrete. Aggregates shipped directly from the producer's washing screens may cause considerable difficulty. Stock piling will alleviate this situation to a great extent as much of the free water will drain off, and the resulting moisture content will be more uniform.

To proportion the materials:

APPROXIMATE ABSORPTION OF WATER BY AGGREGATES

Average sand	1.0 per cent by weight
Calcareous pebbles and crushed limestone	1.0 per cent by weight
Trap rock and granite	0.5 per cent by weight
Porous sandstone	7.0 per cent by weight

APPROXIMATE QUANTITY OF FREE WATER CARRIED BY AVERAGE AGGREGATES

Condition of Aggregate*	Approximate Quantity of Free Water
Very wet sand	6 to 8 per cent by weight
Average sand in stock piles after draining	3½ to 4 per cent by weight
Moist sand	2 per cent by weight
Moist gravel or crushed rock	2 per cent by weight

*The coarser the aggregate, the less free water it will carry.

The moisture content of the materials may be easily obtained by the following method. Select representative samples of the aggregates and accurately weigh out 10 to 20 lb. of each. Guard against evaporation during the interval between sampling and initial weighing. Sensitivity of the scales governs the size of the sample. Thoroughly dry each of the materials. This may be done on a gasoline camp stove or by pouring alcohol over the material and igniting it. The total percentage of moisture $p = 100 \frac{w - w_1}{w_1}$ where p = total percentage of combined absorbed and free water; w = wt. of field condition sample; w_1 = wt. of sample after drying.

The absorption properties of the materials are an important factor in proportioning the ingredients of a batch. If the moisture content of the aggregates is less than required to produce a saturated surface-dry condition at the time the materials are put into the mixer, they will absorb mixing water from the batch and decrease the workability. Aggregates are in a saturated surface-dry condition when they have absorbed all the water possible and the surfaces of the particles are free from water. Free unabsorbed water is also important as it adds to the mixing water. To maintain constant aggregate proportions, the proportions are stated on the basis of saturated surface-dry weights, or oven-dry weights.

Tests made in the laboratory supply the inspector with the specific gravity and absorption of the aggregates. These characteristics ordinarily will not change unless the source of the material is changed.

The following examples show how the foregoing information is used by the plant inspector.

It is required that field proportions be established for a basic mix of 5.5 gal. water, 94 lb. normal portland cement, 188 lb. sand, 316 lb. coarse aggregate, saturated surface-dry weights. The laboratory has furnished the following for the material to be used:

	Sand	Coarse Aggregate
Bulk, specific gravity, oven-dry basis	2.66	2.65
Per cent absorption, oven-dry basis	2.0%	2.5%

Tests of aggregates taken from the stockpiles show the percentage of moisture on an oven-dry basis (including both absorbed and free water) to be 6 per cent for the sand and 1.5 per cent for the coarse aggregate. Both weight of aggregates and water added at the mixer must be adjusted for the free water and absorption of the aggregates. These adjustments are made as follows: The field weight corresponding to 188 lb. of sand saturated surface dry equals

$$W_{F.A.} = \frac{188\ (1.00 + .06)}{1.00 + .02} = 195 \text{ lb.}$$

The field weight corresponding to 316 lb. of coarse aggregate saturated surface dry equals

$$W_{C.A.} = \frac{316\ (1.00 + .015)}{1.00 + .025} = 313 \text{ lb.}$$

Water to be added at mixer = 5.5 gal.$-$

$$\frac{195 - 188}{8.33} - \frac{313 - 316}{8.33} = 5.02 \text{ gal.}$$

This results in the following proportions:

	Water	Cement	Sand	Coarse Aggregate
Basic mix	5.5 gal.	94 lb.	188 lb.	316 lb.
Field mix	5.02 gal.	94 lb.	195 lb.	313 lb.

The volume of concrete that this mix will produce is then estimated:

Specific gravity of cement........................ = 3.15
Bulk specific gravity of sand, oven-dry basis .... = 2.66
Bulk specific gravity of coarse aggregate, oven-dry basis................................ = 2.65

Ingredient		Absolute Volume
Cement	$\frac{94}{3.15 \times 62.3}$	=0.48 cu.ft.
Sand	$\frac{188}{2.66 \times 62.3\ (1.00 + .02)}$	=1.11 cu.ft.
Coarse aggregate	$\frac{316}{2.65 \times 62.3\ (1.00 + .025)}$	=1.87 cu.ft.
Water	$\frac{5.5}{7.48}$	=0.74 cu.ft.
	Total Yield....	4.20 cu.ft.

In other words, this mix would yield 4.20 cu.ft. of concrete per sack of cement if it were air free. However, no concrete is air free. When concrete is made with normal portland cement, air trapped during mixing and placing usually averages about one per cent. On this basis the foregoing mix would yield $\frac{4.20}{1.00 - .01}$ or 4.24 cu.ft. of concrete per sack of cement and would require $\frac{27}{4.24}$ or 6.37 sacks of cement per cu.yd. of concrete.

The foregoing applies where normal portland cement concrete is used. However, air-entrained concrete frequently will be specified—especially in the northern states where severe winters and salt applications to remove ice and snow require that concrete have superior durability. When this is the case, certain modifications must be made in the mix proportions to compensate for the volume occupied by the entrained air and the increased workability of air-entrained concrete.

The many minute air bubbles (3 per cent to 6 per cent of the volume of concrete) contained in air-entrained concrete would increase the volume of mortar over that in the same mix made without air entrainment. This would result in an oversanded mix and a lowered cement factor. To correct for this the sand content required for normal portland cement mixes is reduced by an amount equal to about 3 per cent of the combined weight of sand and coarse aggregate. Yield tests made at the mixer will determine whether further minor adjustment of the sand, and possibly of the coarse aggregate, is required to maintain the desired cement factor and to secure satisfactory workability. To maintain the desired slump it will be necessary to reduce the water added at the mixer approximately ¼ gal. per sack of cement.

The following problem will serve to illustrate how the field proportions for an air-entrained concrete mix are established. The previously mentioned basic mix of 5.5 gal. water, 94 lb. cement, 188 lb. sand, 316 lb. coarse aggregate, saturated surface-dry weights will again be used. It is required that field proportions be established for air-entrained concrete, using this mix as a base. Reduce the sand by an amount equal to 3 per cent of the total weight of fine and coarse aggregate and the water content by ¼ gal. per sack of cement. The new basic weight of sand when modified for use with air entrainment becomes 188 − .03 (188 + 316) or 173 lb. and the water content becomes 5.50 − 0.25 or 5.25 gal.

Using the previously given values for absorption and moisture in the aggregates, the field proportions for a one-sack batch are derived as follows:

The field weight corresponding to 173 lb. of sand saturated surface dry equals

$$W_{F.A.} = \frac{173\ (1.00 + .06)}{1.00 + .02} = 180 \text{ lb.}$$

The field weight corresponding to 316 lb. of coarse aggregate saturated surface dry equals as before,

$$W_{C.A.} = \frac{316\ (1.00 + .015)}{1.00 + .025} = 313 \text{ lb.}$$

Water to be added at mixer = 5.25 −

$$\frac{180 - 173}{8.33} - \frac{313 - 316}{8.33} = 4.77 \text{ gal.}$$

This results in the following proportions for air-entrained concrete:

	Water	Cement	Sand	Coarse Aggregate
Basic mix	5.25 gal.	94 lb.	173 lb.	316 lb.
Field mix	4.77 gal.	94 lb.	180 lb.	313 lb.

An estimate of the volume of concrete that this mix will produce is then made:

Specific gravity of cement........... = 3.15

Bulk specific gravity of sand, oven-dry basis .... = 2.66

Bulk specific gravity of coarse aggregate, oven-dry basis........ = 2.65

Ingredient		Absolute Volume
Cement	$\frac{94}{3.15 \times 62.3}$	=0.48 cu.ft.
Sand	$\frac{173}{(1.00+.02)\ 2.66 \times 62.3}$	=1.02 cu.ft.
Coarse aggregate	$\frac{316}{(1.00+.025)\ 2.65 \times 62.3}$	=1.87 cu.ft.
Water	$\frac{5.25}{7.48}$	=0.70 cu.ft.
	Total air-free volume	=4.07 cu.ft.

It is anticipated that concrete made with this mix, using either air-entraining portland cement or normal portland cement in conjunction with a mixer addition of an acceptable air-entraining material, will have an air content between 3 per cent and 6 per cent. In lieu of experience from trial batches or until such time as construction begins, it can be assumed, for making a preliminary estimate, that the air content will be 4.5 per cent. On this basis the air-entrained concrete mix would yield $\frac{4.07}{1.00 - .045}$ or 4.26 cu.ft. of concrete per sack of cement and would require $\frac{27}{4.26}$ or 6.33 sacks of cement per cu.yd. of concrete.

Gravimetric mix analyses (such as the preceding examples) made prior to construction are invaluable to the inspector. They permit the establishment of accurate trial proportions needed to begin paving operations.

The cement actually used each day should be compared with the computed amount derived from yield tests made at the mixer. This is necessary in order to know that the minimum cement requirements have been satisfied. The following example will show how this is done. Suppose the series of periodic unit weight determinations made during the day on fresh concrete taken from the mixer averages 147.5 lb. per cu.ft. Further, the average batch weight is 5,500 lb. (actual scale weights of sand, gravel and cement, plus weight of water added at the mixer) for batches from which concrete was sampled for the unit weight determinations. Therefore, each batch mixed during the day yielded an average of $\frac{5{,}500}{147.5}$ or 37.29 cu.ft. of concrete. The minimum cement factor specified for the job is 6.33 sacks per cu.yd. The concrete made that day would then average $\frac{37.29 \times 6.33}{27}$ or 8.74 sacks of cement per batch. If the batch meter indicated the day's production to be 400 batches, the amount of cement which should have been used to yield this quantity of concrete is 8.74 × 400 or 3,496 sacks.

It is known that 825 lb. of cement went into each of the 400 batches. The amount of cement actually used is then $\frac{400 \times 825}{94}$ or 3,511 sacks. In this case there was an overrun of 3,511−3,496 or 15 sacks of cement. Expressed on a percentage basis, the overrun is $\frac{15}{3{,}496} \times 100$ or 0.4 per cent.

The inspector at the mixer must make yield tests at regular and frequent intervals to insure that the average results obtained are representative of the day's operations. If this is done, reliable checks on the cement used will be obtained.

FORM SETTING

To obtain a smooth-riding surface, well-supported and correctly aligned forms are essential.

THE inspector should make certain that the steel forms to be used have a base-to-height ratio at least equal to that specified and that wooden forms are of the required thickness. Reject all forms which show a variation under a straightedge exceeding the allowable tolerance. A finishing machine cannot produce a smooth-riding surface when operating on crooked forms. Since finishing machine wheels ride on the flange of the forms, these should be inspected to see that they are not bent up or down. Broken joint locks on steel forms invite form settlement.

Forms should be supported on a uniformly firm foundation for their entire bearing area. When the forms are propped up with stones or pieces of wood, surface irregularities are common. Considerable handwork, causing additional expense for finishing, is required to correct errors due to form settlement. Since the subgrader and finishing machines operate on the forms, the evenness, or riding quality, of the finished pavement depends upon the trueness of the forms.

See that no form pins or wedges are omitted and that wood forms are securely braced. Observation of form movement under a moving finishing machine will assure you this is necessary to hold the form as originally set.

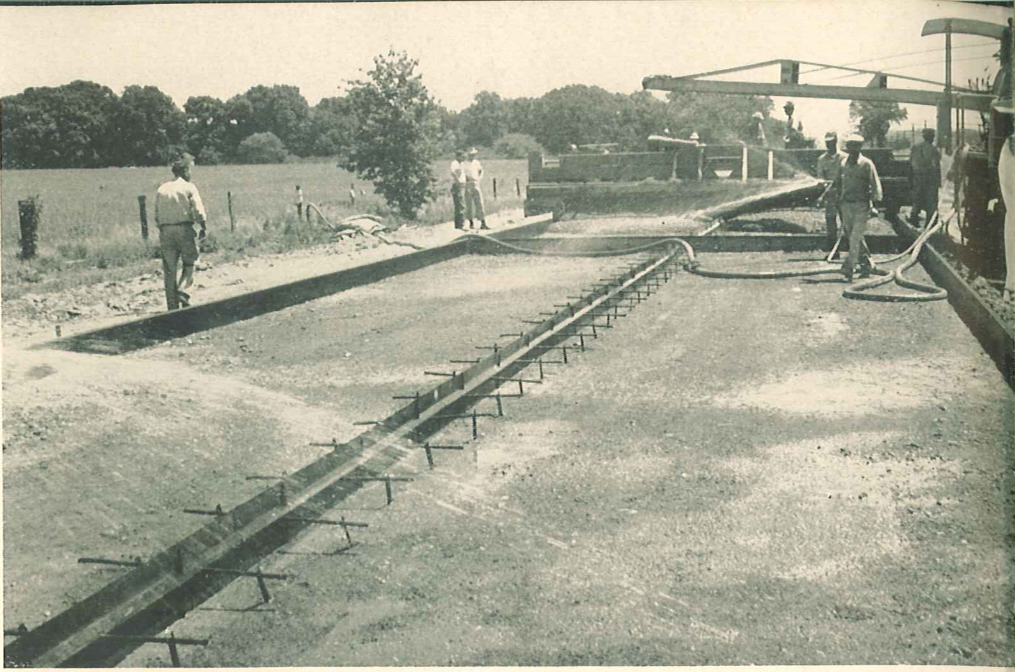
After the side forms have been securely set to line and grade, a final check of both horizontal and vertical alignment should be made by sighting along the tops of the forms. Minor irregularities are found to be present which can be detected in no other way.

Any forms which must be raised should be removed and additional soil tamped in place to bring the form to new grade unless there are available proper form tamping tools which will permit additional fill to be tamped under the form from the sides without removal of the form.

Painting the inside of the forms with oil just before the pavement is laid is an important requirement. This prevents concrete from adhering to the forms and enables them to be stripped and cleaned more easily. The edges of the forms should be kept clean. Cleaning is particularly necessary along the edge used in gaging the concrete surface.

Flanges of forms are sometimes bent as they are pulled. The inspector should insist on methods of pulling which will not injure the forms.

The importance of careful form setting cannot be overemphasized. By diligent and conscientious attention to this detail of construction, the inspector saves the contractor needless expense, himself from future grief, and a smooth-riding surface is made possible.



PREPARING THE SUBGRADE

Rough grading is usually completed before the concrete inspector arrives on the job. The fills have been in place long enough to allow for settlement, and the ditches have been cut to approximate grade.

Before subgrading begins, check with the foreman the amount of compaction he expects under the roller. Preliminary shaping of the subgrade should leave it high to allow for this compaction. After the grade has been rolled it should be carefully checked and any variations from the true subgrade corrected. It should be borne in mind that variations in the subgrade mean variations in the pavement thickness.

Either hand or mechanical methods may be used in subgrading. The former, however, requires greater care and more frequent checking.

If a subgrader and planner are used, the cutting blades should be carefully set to the correct depth with the machine in its normal position. The equipment may be raised to facilitate checking by placing blocks under the flanged wheels which ride the forms. Deflection of the machine from its own weight will often seriously affect settings of the cutting blades if the machine is not in a normal position. Use piano wire or fish line for checking and pull it taut.

Rapid drying out of concrete during the hardening period causes shrinkage at a time when the concrete does not have sufficient strength to resist the stresses which are set up. To minimize this, the subgrade should be in a moist condition at the time concrete is placed, otherwise mixing water will be too rapidly absorbed from the concrete. Subgrade sprinkling should be done far enough in advance of paving to allow absorption of the water, leaving a moist, but not a muddy surface.

Advancements made in highway soil technology in recent years have been remarkable. Many state highway departments now have well-equipped soils lab-

Mixing water will not be too rapidly absorbed by a subgrade which has been properly moistened.

oratories and trained field soil engineers, as do many county and city engineering departments. They are equipped to study any unusual or unstable soil condition and to recommend the correct treatment. If you have any reason to believe that parts of the subgrade on your job are or will become unstable, notify your superior. He will make arrangements to have those areas investigated and treated. Keep your eyes open for soft and spongy places in the grade. Do not overlook areas that may develop into frost boils or wet weather seeps. Some of the heavy clays are highly expansive and in certain climates may require special consideration.

Subgrades for city pavements will be better, generally, than rural highway subgrades as municipal sewer systems tend to keep the soil well drained. Often, however, this relationship is reversed because utility trenches are carelessly backfilled.

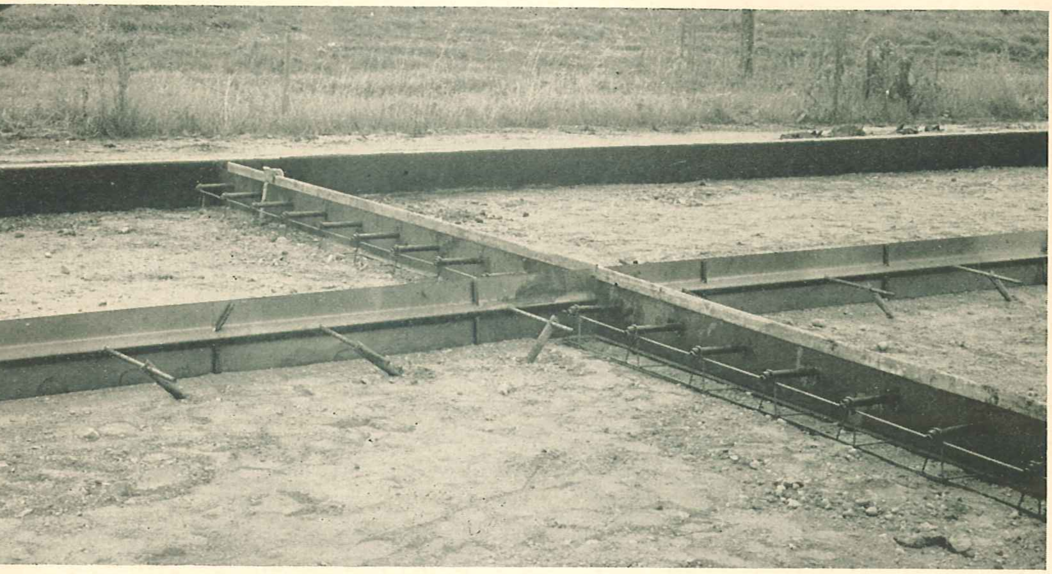
The inspector should see that all old trenches which are exposed during the preparation of the subgrade and all new trench backfills are as firm as the surrounding soil. Further compaction, many times, can be effected by jetting. Repeated rolling and filling of the settled trench is another method which may be used if the soil will not slake in water. Old excavations sometimes remain for years with a thin crust of compact earth arched over a large cavern. Such places may often be detected by the hollow sound made when vehicles pass over them. The washing of soil into nearby sewers by leaky water pipes is a common cause of hollow subgrades.

When city pavements are to be reconstructed wider than their original width, the location of utility poles, fire hydrants and buffalo boxes must be checked. If they interfere with construction the proper officials should be notified. Sufficient time should be given for their relocation so that the contractor will not be delayed.

A notebook record of the location of all sewer manholes, catch basins, water valves, and utility manholes which fall within the curb lines will prove to be worth many times the effort of preparing it. Sometimes, grade and crown revisions leave the top of existing covers below subgrade. Such covers may be paved over unless a record has been kept of their location.

Advise your superiors of any underground structures which, in your opinion, need repairing or reconstructing, so that arrangements can be made to correct their condition before paving. Criticism is invited when it is necessary to tear up a pavement to repair an underground structure which should have been taken care of at the time the street was paved.

Cover for all underground structures should be set accurately to grade if a good riding pavement is to be obtained. Care must be exercised to place the covers so they will conform as nearly as possible to the crown of the pavement. If the pavement crown is constant, covers are readily set to grade by means of a template, but if the crown is variable, the grades must be computed and the covers set with string line, tee sticks or a level. Be sure that frames for the covers are set in a full bed of mortar.



Adequately supported joints, tiebars and dowels will hold their alignment during the placing and finishing of the concrete.

JOINTS

THE only difference between good joints and poor joints may be the difference between careful workmanship and slack workmanship.

There are three major types of joints: expansion, contraction, and hinged joints. Many varieties of these types are in use today, their relative merits not being subject for discussion in this manual.

All expansion and contraction joints should be placed at right angles to both subgrade and center line of the pavement. Transverse joints must be continuous across the pavement from edge to edge. When metal longitudinal joints are used they must not be continuous across transverse joints.

Expansion material must extend continuously from top to bottom of the slab and from edge to edge, completely separating the adjacent slabs. When the side forms are removed, any wedges of concrete across the ends of the joints should be removed. If concrete spans the joint at the end or in the interior of a slab it prevents free expansion, and cracking or spalling will result.

Load transmission bars through expansion and contraction joints should be parallel to both the subgrade and the center line of the pavement. Some types of joints provide rigidity to the dowel by means of its mounting in the joint. Other types rely on chairs driven into the subgrade for support. Great care must be taken with this latter type of installation to prevent shifting of the bars. Workmen stepping on them or careless discharging of concrete with the spreader bucket are common causes of displaced dowels.

It is extremely important that bond between the portion of the dowel on one side of the joint and the concrete be prevented or the joint will be unable to open and close. Tests have shown that painting and oiling of dowels prevent

approximately 90 per cent of the bond between the bar and the concrete. One coat of basic sulphate blue lead paint followed by oiling has been found satisfactory.

Space must be provided by caps at one end of each expansion joint dowel into which the dowel may slip as the joint closes. If this space is not provided, the free movement of the slab is obstructed and the joint will be unable to function as intended.

Dowels through contraction joints must be painted and oiled on one side of the joint, as described for expansion joints, but no caps need be provided for expansion at the dowel ends. Dowels cut to length by shearing are often deformed at the ends. Such bars should be ground so that there are no burrs or deformations to interfere with the action of the dowel.

The required tiebars should be placed across the hinged longitudinal joint. If this is not done the slabs may separate slightly, thus weakening the slab next to the joint and causing interior corner breaks. It is important that the tiebars at each side of a transverse joint are not more than 15 in. from the transverse joint. A hinged joint must be tight to be effective, whether it depends on dovetailing (deformed metal joint) or aggregate interlock. The latter type is generally constructed by forming a groove in the pavement to a depth equal to one-quarter the center thickness of the pavement. Under no condition should the groove exceed one-third the pavement thickness. The interlocking aggregate in the crack which will form below the groove serves to transfer load from one slab to the other, providing the groove is not cut too deep.

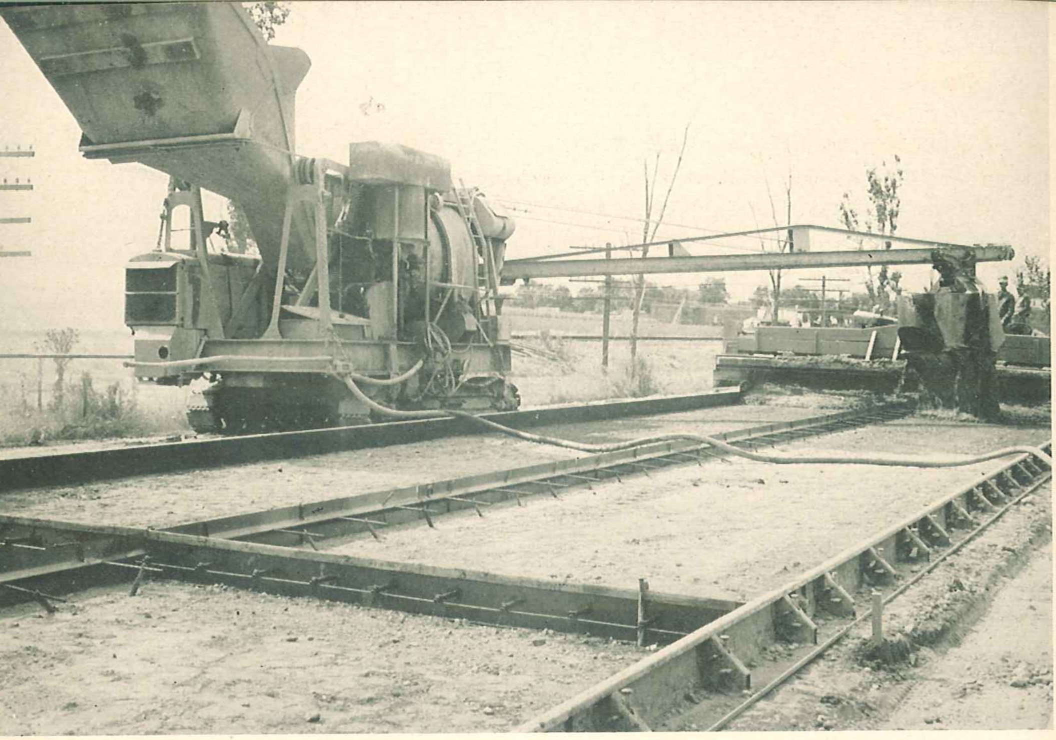
The type of joint where the slab division is made by forming a groove in the pavement is sometimes referred to as a dummy joint. When it is used as a contraction joint, in combination with and spaced between expansion joints, the aggregate interlock may not effectively transfer loads from one slab to another and dowels or other transfer devices may be specified.

Best results in finishing a surface at joints will be obtained if the joint material is set $\frac{1}{4}$ in. below the pavement surface and a steel cap is placed over the filler. This is done so that no displacement will occur during the finishing operation. It is then possible to finish directly across the top of the joint. If difficulty is experienced, the screed may be lifted slightly a few inches in advance of the joint, then lowered directly on top of it and the screeding operation continued.

The inspector should check the surface at each joint with a 10-ft. straightedge. The straightedge is so placed on the pavement that it extends on both sides of the joint materials. The slightest visible inequality should be corrected at once. The edges of the joints must be rounded to a small radius, and the inspector should see that no ridges of concrete are left by the edger after finishing the joints.

Great care must be exercised to be sure that the groove above the expansion joint material is exactly over, and is the full width of the joint material, but no wider. It is good policy to scrape the top of the joint material the day following installation so that it is visible for its full length and thickness.

When poured joint filler is used, the bulkhead is beveled to permit its easy removal. It is removed when the concrete has hardened sufficiently to preserve the slot into which the filler is to be poured. The slot must be free from stones or debris. Hot filler will contract as it cools and the joint must be poured several times to fill it just flush with the surface. Fine sand is usually dusted over the filler to prevent its being picked up by traffic.



Careless handling of water hose or improper placing of concrete will force adequately supported joints and steel out of alignment.

AT THE MIXER

MIXING concrete and placing it on the subgrade is, perhaps, the most important item in construction of a concrete pavement and requires the inspector's most careful attention. There are countless items to watch.

A few tests made before paving is started will prevent lost time during construction.

Inspect the condition of the buckets and blades in the mixer drum. If they are badly worn the result will be a poor job of mixing.

Calibrate the water gage by draining the water tank on the paver into an old oil barrel or similar container. An inner tube which has been cut to form a hose may be attached to the water tank outlet to drain the water into the drum. The volume of the water may be obtained either by actual measurement or by weight. This procedure must be followed for several settings of the gage, covering a range somewhat wider than will be used in practice. These volumes should check the water gage settings on the mixer. If they do not check, a calibration curve may be plotted to show what gage setting must be used to yield the required amount of water.

See that the discharge valve which controls the injection of water into the drum does not leak.

Check the timer on the mixer. Make certain that it is properly connected to automatic lock on the discharge and that the batch cannot be discharged until the set time interval has elapsed.

Inspect the batch counter. It should be in good order and kept that way throughout the job.

Forms must be in good alignment and set at the proper grade, with enough

bearing to hold them rigidly while the concrete is being placed and finished. It is well to watch the forms behind the mixer and, if displacement is observed, insist that they be set more securely in the future.

Check the camber in the finishing machine screeds to make sure they are adjusted to produce the specified cross-section. To obtain a positive check, measure from a piano wire or fish line pulled taut across the finished pavement.

Check the subgrade templet and watch it carefully at all times so that all high spots on the subgrade are corrected. Make sure that all ruts left by the mixer or trucks are ironed out. Earth added to bring low spots to grade must be hand tamped until it is as firm as the rest of the subgrade.

Ordinates for checking the camber of the finishing machine screeds, the subgrade templet and the cross-section of the pavement surface may be readily computed for the specified crown and width of pavement. The following example illustrates the computations in determining crown and subgrade ordinates for a $1\frac{1}{4}$-in. parabolic crown on a 20-ft. pavement.

Divide one-half the pavement width into any number of equal parts. In this instance 10 divisions have been made so that ordinates may be obtained at 1-ft. intervals.

The ordinate or distance down to the surface of the pavement from the crown elevation at any point is then a function of the square of the relative position of that point. For example:

If Point No. 0 is at the center line of the pavement and Point No. 10 at the edge, the position of Point No. 6 is $\frac{6}{10}$ of the distance from the center line to the edge of the pavement. Its ordinate is therefore $\frac{6^2}{10^2} \times 1.25$ in. $= .36 \times 1.25$ in. $= .45$ in. $= \frac{29}{64}$ in.

The ordinates for each of the other points will be:

ORDINATE OF POINT

No. 0 =	$0 \times 0 \times 1.25$ in. = 0.00 in.
No. 1 =	$.1 \times .1 \times 1.25$ in. = .01 in.
No. 2 =	$.2 \times .2 \times 1.25$ in. = .05 in.
No. 3 =	$.3 \times .3 \times 1.25$ in. = .11 in.
No. 4 =	$.4 \times .4 \times 1.25$ in. = .20 in.
No. 5 =	$.5 \times .5 \times 1.25$ in. = .31 in.
No. 6 =	$.6 \times .6 \times 1.25$ in. = .45 in.
No. 7 =	$.7 \times .7 \times 1.25$ in. = .61 in.
No. 8 =	$.8 \times .8 \times 1.25$ in. = .80 in.
No. 9 =	$.9 \times .9 \times 1.25$ in. = 1.01 in.
No. 10 =	$1.0 \times 1.0 \times 1.25$ in. = 1.25 in.

The same ordinates apply to each half of a pavement with symmetrical crown, again numbering the points from center toward the edge.

It is better to have the subgrade thoroughly wet a day ahead rather than just before placing concrete. If sprinkling is done immediately ahead of the mixer, care must be taken that the stream of water does not throw earth on the edge of the concrete being placed. Even a slight covering of dirt or dust might cause a plane of weakness, resulting in a ragged crack.

When the batch is placed on the subgrade, shovelers must be careful not to get earth mixed with the concrete.

Workmen must not walk on the soft concrete after it has been struck off. Boot tracks are usually filled with "soup" which will shrink when setting and cause a soft spot which will readily develop into a hole.

Surface of concrete must be watched constantly for high and low spots.

It is important that the concrete shoveled against the forms be not deficient in mortar, otherwise the edges of the slab will show honeycomb after the removal of forms. If the workmen will turn the back of the shovel toward the form when the concrete is placed against the forms, results should be satisfactory. Reinforcing steel must not be displaced and there must be a proper covering of concrete above it.

If the mixer is shut down for only a short period, making it unnecessary to install an expansion or construction joint or to remove the concrete already placed, there should be a thorough mixing of the fresh concrete with that already in place when mixing operations are resumed.

Too much mixing water reduces strength of concrete. It is important that slump tests be made often enough to provide a basis for control of the consistency.

Time of mixing is important. See that the specified time is rigidly adhered to. Check timer on mixer frequently and see that it is not tampered with.

Stationing stakes which have been placed next to the edge of the pavement provide convenient ties from which to record the locations of any unusual conditions, the correct locations for placing joints, and the linear feet of concrete placed during any period.

General weather conditions should be recorded at the beginning and ending of work each day, as well as any unusual conditions arising during the day. This information should include temperature, condition of the wind, shutdowns, equipment difficulties, etc.

It is important that an accurate count be made each day of the actual number of batches which were placed at the mixer. It is then possible to check the amount of material leaving the proportioning plant.

As has been pointed out previously under the heading "At the Proportioning Plant", the yield test provides a means of comparing the amount of cement actually used during any day's operations with the amount which should have been used to meet the minimum cement content requirement. In addition the yield test provides a means of comparing the volume of concrete actually produced with the volume required for that day's work. Yield tests should be made at least twice each day. Additional tests are desirable and necessary if the materials or mix are changed. A ½-cu.ft. measure, a steel rod, a trowel and scales are required to determine the yield.

Each day the inspector should compare the volume of concrete produced with that required for the pavement constructed. Any difference will be due to the fact that:

1. Tests for yield were not made at sufficient frequency to obtain average results representative of the day's operation.
2. The average thickness or width of pavement placed varies from plan requirements.

For example, suppose that 400 batches were used to place 1,215 lin.ft. of pavement having a width of 20 ft. and a uniform thickness of 7¼ in. The quantity of concrete required to place this pavement is $\frac{1{,}215 \times 20 \times 7.25}{12 \times 27}$ or 543.7 cu.yd. Taking the average batch weight for the day to be 5,500 lb. (total scale weight of cement, sand and coarse aggregate, plus weight of water added at mixer) and the average unit weight of the concrete to be 147.5 lb. per cu.ft., the quantity of concrete actually produced is $\frac{5{,}500 \times 400}{147.5 \times 27}$ or 552.4 cu.yd. Comparing the two quantities, there is an overrun of $\frac{552.4 - 543.7}{543.7} \times 100$ or 1.6 per cent. It is common practice to accept an underrun or overrun not to exceed 2 per cent as the permissible tolerance. In case the variation exceeds 2 per cent, the inspector should immediately check to determine whether the required width and thickness of pavement are being obtained. Forms may be improperly spaced, the subgrade may be high or low, the finishing machine screeds may be out of adjustment, or the forms may have

An experienced inspector can detect variations in the consistency of the mix by its appearance as it leaves the bucket.

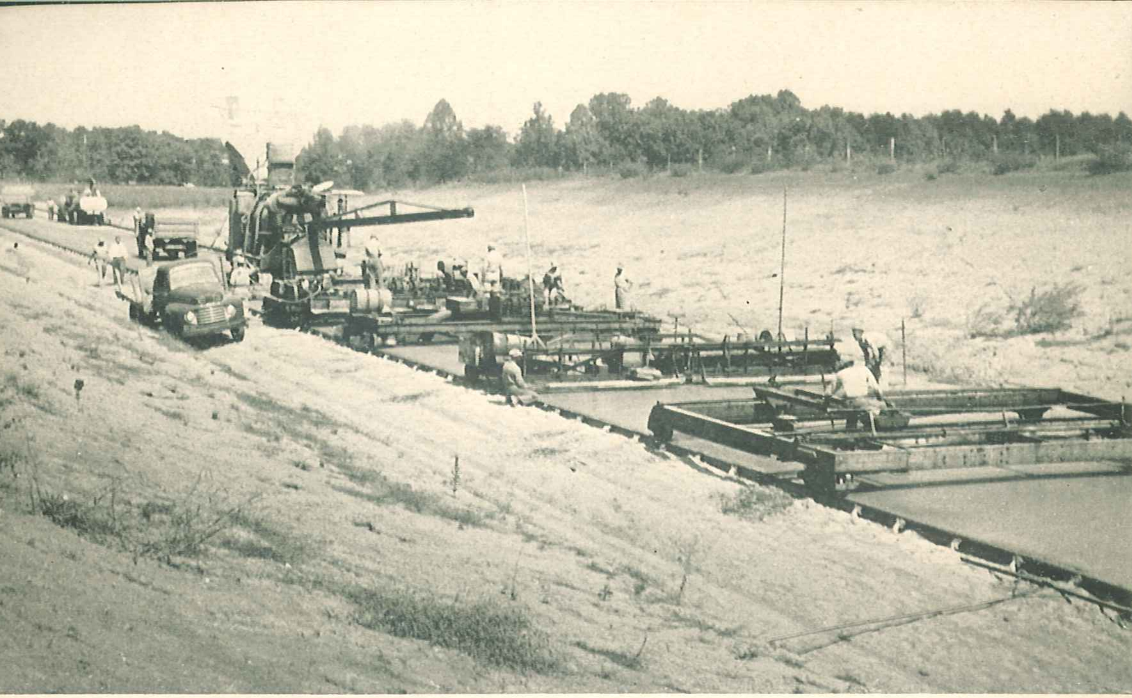
settled under the weight of the finishing machine.

When air-entrained concrete is used, the inspector should make periodic determinations of the air content of the concrete. If the air content does not fall between the specification limits (usually 3 per cent to 6 per cent), necessary steps should be taken to remedy the situation immediately.

Should the air content be too high there will be an unnecessary reduction in the strength of the concrete without any gain in durability. If this occurs when air-entraining portland cement is being used, lower air contents may be obtained by blending with normal portland cement or by securing a different lot of air-entraining portland cement. When air entrainment is being secured by mixer addition of an air-entraining material, lower air contents may be obtained by reducing the quantity of material being added.

If the air content of the concrete is less than 3 per cent, the pavement may lack satisfactory resistance to freezing and thawing and to the action of salts applied for snow and ice removal. Should the air content of the concrete when made with air-entraining portland cement be too low, this situation may be corrected by adding at the mixer a suitable quantity of the same air-entraining material as was incorporated in the air-entraining portland cement during manufacture, or a new lot of air-entraining cement may be secured. When air entrainment is being obtained through mixer addition of an air-entraining material, higher air contents may be secured by increasing the amount used.

When air entrainment is to be accomplished through addition of an agent at the mixer, the inspector should make certain that the specified agent is used and in the required amount. It should be added at the mixer by means of a reliable automatic dispenser. When the agent is added manually, careless measurement and inadvertent omission or duplication of the air-entraining material are to be expected. Such errors will seriously affect the air content of the concrete and the quality of the finished pavement.



Modern finishing machines produce remarkably true and easy-riding surfaces.

FINISHING THE SURFACE

PAVEMENT is judged by its surface. Few users know what materials went into the slab, how carefully it was designed or how conscientiously construction details were carried out. But if it does not ride smoothly, or if surface defects appear, everyone knows it and calls the entire job "bad". In no other part of pavement construction is the inspector so absolutely responsible for quality as in surface finishing. He alone determines whether the riding public will condemn or approve the work.

If the forms have been set in good alignment and firmly supported, and if the design of the mix is such that the concrete has the right workability, the finishing machine should produce a satisfactory surface with no more than two passes of the machine. Hand-finishing with floats behind the finishing machine often harms rather than improves the pavement surface. Too much manipulation of the concrete is detrimental to the wearing surface. Scale has often been attributed to over-manipulation.

With either machine- or hand-finishing a nearly uniform amount of concrete should be carried ahead of the screed. Too much material will tend to lift the templet above the forms, causing ridges, while too little will leave low spots in the surface.

Where tamping is specified, this should cease as soon as the coarse aggregate is submerged. Too much tamping brings an excess of mortar to the surface, and may cause scaling. Tamping is

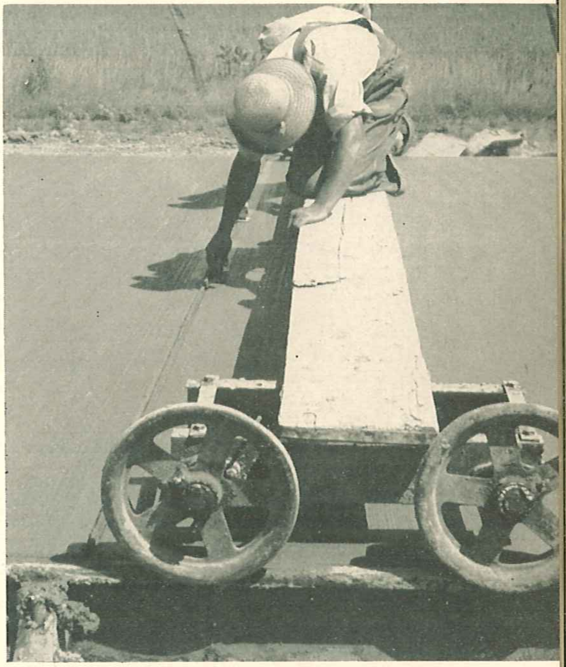
unnecessary with concrete of suitable consistency and workability. It is essential that all finishing operations be reduced to a minimum.

A longitudinal float has proved helpful in decreasing longitudinal variations in the surface. Careless handling, however, will result in more harm than good. Some contractors obtain best results by simply dragging the float across the pavement, while others prefer to oscillate it longitudinally as it is being moved transversely. Care must be exercised in using the latter method to prevent the end of the float from leaving a small ridge of mortar across the pavement.

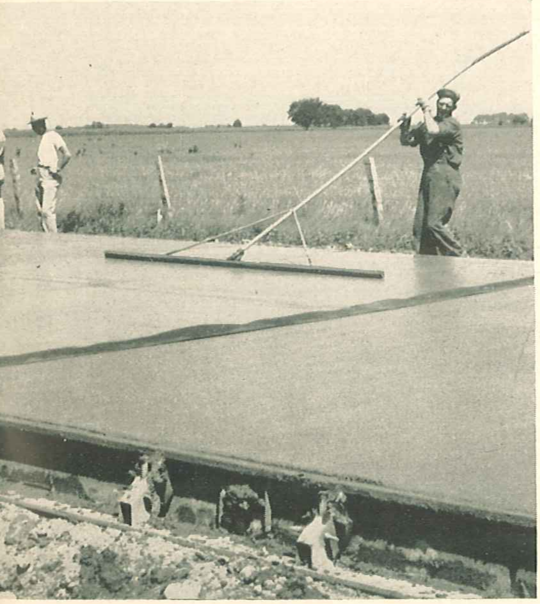
A 10-ft. straightedge pulled from the center to the form will serve to remove any minor surface irregularities and laitance (excess mortar). The surface should appear uniformly dense without any coating of weak mortar or scum that will later scale off. The use of a 10-ft. straightedge should be emphasized.

Concrete should be of such consistency and so manipulated that one belting is sufficient. If excess water should appear on the surface after belting, it should be removed by the use of a wide strip of wet burlap used as a belt or dragged over the surface. When the pavement is constructed in longitudinal strips or panels about 10 ft. wide, two screedings and one belting are, in general, sufficient.

The pavement adjoining expansion joints must be edged and all concrete cleaned off the top of the joint material.



Transverse and longitudinal joints are finished by workmen operating from a movable bridge.



Early straightedging permits the correction of surface irregularities while the concrete is still plastic.

Longitudinal center joints may or may not be edged to function efficiently. Edging them, however, improves their appearance, eliminates spalling and reduces maintenance costs. Contraction and construction joints should be edged.

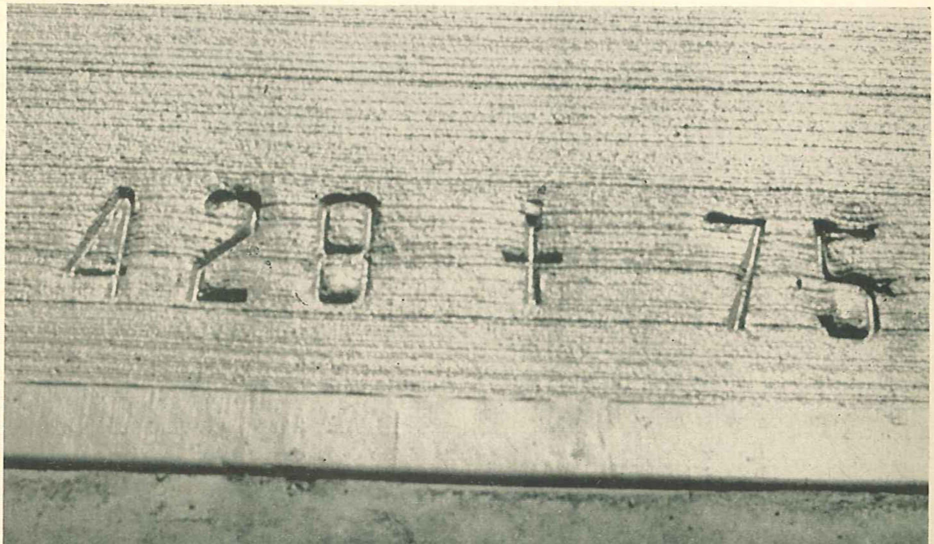
During the finishing operations the inspector should check the surface contour by eye, calling attention to any irregularities. After the concrete has become firm enough to support a straightedge, but before it has become too hard to permit alteration, it should be checked with the straightedge. High spots must then be levelled and low spots brought to grade until the entire surface is true and within the specified limitations.

Remember you're not building a dance floor. A gritty surface will improve the traction of moving vehicles.

When air-entrained concrete is being used, some modifications in the finishing procedures are necessary because air-entrained concrete is almost free from sedimentation or bleeding. As a consequence little free water is left on the surface for lubrication during finishing operations. This condition is more pronounced when the air temperature is high, the relative humidity low and when the wind is blowing briskly. Therefore, the inspector should see that hand-finishing operations follow closely behind the finishing machine. If this is not done, drying will harden the surface and make it impossible to obtain a good finish. Occasionally the concrete will adhere to the finishing machine screeds, causing a torn surface. Increasing the ratio of screed oscillation to the speed of forward travel will generally overcome this difficulty.

The date and station number should be neatly inscribed in the pavement surface at the start of each day's run. These will prove to be of real value when inspections of the pavement are made in later years.

Commercial steel dies were used to inscribe this station number placed at the start of a day's work.



Burlap and similar types of protective covers are placed as soon as possible and wetted immediately.

CURING

MANY tests have been made to show the importance of protecting concrete from drying too rapidly while hardening. These indicate that both the compressive and the flexural strength as well as resistance to wear are so materially increased by proper curing that this phase of construction must be given careful attention.

By keeping concrete damp for the first 3 days, the modulus of rupture is increased about 20 per cent, and resistance to wear is increased about 35 per cent. Seven days' protection increases the modulus of rupture about 30 per cent and the resistance to wear about 40 per cent. When, in addition to rapid drying out, the pavement is subjected to the heat of the summer sun, the effect on the top half-inch is especially severe.

Pavement should be protected the full time required by specifications. These sometimes provide that pavement may be opened when satisfactory strength is shown by tests. It is during the first few days that pavements are most affected by drying and the first 24 hours are the most important of all. Strength lost by failure to keep pavement moist during the early hardening period cannot be wholly regained by subsequent wetting.

In hot weather the pavement should be protected as soon as the last finishing operation is completed. This is best done by placing a wet burlap or cotton mat cover over the concrete and sprinkling it with a fine spray. The use of these covers has also, to a large extent, eliminated trouble from hair checking which was caused by the surface of the concrete drying out and contracting more rapidly than the mass of the concrete below. The covers must be placed on the concrete so that they will not mar the surface and they must be kept saturated.

The burlap or cotton mat covers may be left in place for the full curing period, or after the pavement has hardened sufficiently they may be removed and replaced by a covering of earth, hay or straw. On comparatively flat grades curing is often effected by covering the concrete with ponds of water, held in place by earth dams built along edges and at intervals across the pavement.

If an earth covering is used it should be at least two inches thick and of a soil which will hold moisture. Stones or hard

Even with mechanical spreaders the inspector must make certain that the required quantity of membrane curing compound is applied per square yard.

lumps have no value as curing agents. Make sure that it is kept wet for the specified period.

Hay and straw absorb moisture readily and retain it well. They must be free from stable manure and must cover all parts of the pavement to a depth of six inches. The insulating properties of hay and straw reduce the temperature variations in the pavement and thus protect it from temperature stresses during the early period when the concrete has little strength to resist them.

Some specifications provide for curing by covering the pavement with waterproof paper, wet burlap or saturated cotton mats for the full curing period. Cotton mats are also effective in protecting the newly placed concrete from temperature stresses.

Whatever wet method is adopted, it is the inspector's duty to see that the entire pavement from edge to edge is kept damp during the entire curing period. Curing is so important that, if there is not enough water for both mixing and curing, the mixer should be stopped.

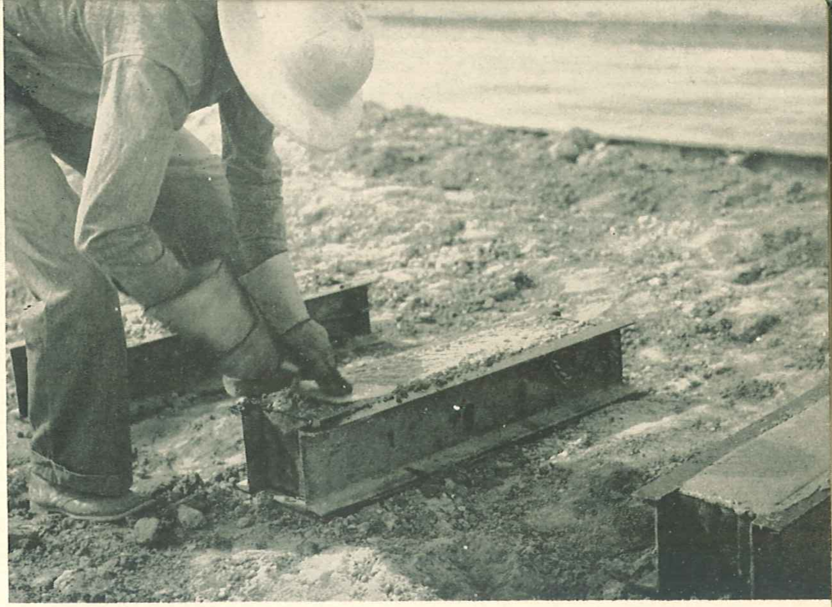
When calcium chloride, bituminous or nonbituminous membrane seal coats are used, the provisions of the specifications as to quantities and time and method of application should be carefully observed.

Calcium chloride curing is not effective in arid or semi-arid districts where there is insufficient moisture in the air to keep the calcium chloride in solution during the heat of the day when the moisture is most needed. Tests have shown a marked deficiency in strength of concrete cured under those conditions.

Bituminous and nonbituminous membranes if properly applied prevent evaporation from the surface and the retained water provides excellent curing. Where bituminous membranes are used, like all dark colored objects, pavement temperatures rise rapidly during the day and fall with similar rapidity during the night. In areas of especially brilliant sunshine the temperature range has caused early cracking of the concrete. This can be avoided by covering the bituminous coatings with whitewash to protect them from the sun. The nonbituminous membranes, being clear or only lightly colored with a quick fading organic dye, need no such protection from the sun.

Extreme caution must be exercised when using any type of membrane cure to make certain that it is applied uniformly and in sufficient quantity to provide a waterproof coating. If this is not done, the quality of the concrete will be greatly reduced.

The inspector must see that the necessary barricades are erected and maintained at all intersections and closures.



The casting of test beams should be done by the inspector, not by a laborer.

TESTS FOR CONCRETE

THE allowable range of consistency or stiffness of concrete is generally stated in the specifications. This is most commonly measured by the slump test. Engineers usually specify one to three inches as the desired slump for paving.

The only special equipment needed for making the slump test is a light sheet metal form shaped to mold a frustum of a cone and a $\frac{5}{8}$-in. bullet-nosed steel rod. The sheet metal mold is 12 in. high and has top and bottom diameters of 4 and 8 in. respectively.

To obtain the slump of a batch of concrete, select a representative sample and fill the mold in layers about 4 in. deep, rodding each layer 25 times with the steel rod. Strike off the top, lift the cone, place it alongside the concrete, and measure the settlement in inches. Best results will be obtained if this test is performed on a small firmly supported wood platform, care being taken to prevent the cone from rising as the concrete is tamped in place. Be sure the sample is representative. Do not take concrete which obviously contains more than the correct proportion of coarse aggregate or that appears to contain more or less water than normal.

After conducting a few tests the inspector will find that he is able to estimate the slump very closely merely from the appearance of the concrete as it comes from the mixer. Then the actual test need only be made occasionally to refresh the memory or to settle a dispute.

When concrete cylinders are cast for subsequent compression tests, the same care should be used in selecting a truly representative sample. In fact, it is well to use the same batch of concrete selected for the slump test. Cylindrical molds, 6 in. in diameter and 12 in. in height, of metal or waterproof pasteboard are commonly used in casting compression cylinders. Two plates are also required for each cylinder cast in open end steel molds. They may be either plate glass or machined metal, but

The air content of the fresh concrete is easily determined with a pressure-type air indicator.

they must have a truly plane surface. One of these plates is put under the cylinder as it is cast; the other is laid on top of it, the object being absolutely true ends.

The selected sample, carried in pails to a place near the mixer where the cylinders are to be cast, should be deposited in the mold in layers approximately 4 in. thick, and rodded as for the slump tests. The metal molds are removed after not less than 16 hours. They must be cleaned and oiled before the next cylinders are cast. The pasteboard mold is left on the cylinder until it arrives at the laboratory. It protects the concrete from damage, but is not of such constant diameter as the sturdier metal mold.

As soon as the forms are removed, the date and any identifying marks should be painted on the cylinder. A record should be kept of the location in the pavement of the batch from which cylinders were made.

Concrete pavements rely on their flexural strength to resist loads. Hence the beam test is more analogous to stress produced in a pavement slab. Test beams have not been standardized as to size, but most engineers use a test beam 6x6x30 in., obtaining two breaks from each beam. Equipment now available makes field flexure tests quite simple.

Where beam specimens are made for the transverse test, care should be exercised in preparing the sample. Concrete should not be tamped into the form but should be placed in two equal layers, each one being rodded. Then the sides and edges are spaded with a trowel and the top struck off and finished with a float. The beams should be covered immediately with damp burlap and after the forms are removed they should be cured by the same curing method as used for the pavement. The beams may be tested by cantilever, center, or 1/3-point loading, but the latter is recommended and has been adopted as standard and by the American Association of State Highway Officials. Modulus of rupture for beams broken by the 1/3-point loading is $R = \frac{WL}{bd^2}$.

Where R equals the modulus of rupture, W equals the applied load in pounds, L equals the length of the span, b equals the breadth of beam and d equals depth of beam, all lengths being in inches.

CURB AND GUTTER

Joints in the curb and gutter should coincide with the joints in the pavement.

An excellent curb and gutter adds much to the appearance and usefulness of a city street.

During grading operations the earth subgrade along the side of the street is less likely to be compacted by traffic than the rest of the roadway. Therefore, it should be rolled carefully or the gutter may settle until it is below the pavement. Rolling is best accomplished by requiring that the whole roadway be rough-graded before curb forms are set.

The inspector should see that the alignment of curb forms is perfect before concrete is placed and he should carefully check by eye, the alignment of the curb face before the concrete has hardened. If there is any visible variation from a true line, the curb should be pushed in or out by exerting or relieving pressure on the back forms. The line of the front of the curb is more important than the back because the latter will be partly covered.

Forms for the gutter face warp and twist badly if they are slotted to allow easy removal from curb and gutter having projecting tiebars. This has led to the use of "L" shaped tiebars (providing mild steel bars ½-in. or smaller are used), one leg of the L being clinch nailed to the inside of the gutter face form and the other leg embedded in the gutter flag. After removal of the forms, the end of the bar is pried out far enough from the concrete to permit slipping a pipe over it which is then used to straighten the bar. Strips of deformed metal, such as that used for center joints, may be placed against the form and the steel bars bent to rest in the groove. The bars can then be straightened and the strips removed and reused. If the pavement is constructed before the curb and gutter, tiebars may be inserted in the pavement in the same way.

A sufficient number of curb clamps and spacer plates should be on hand to provide adequate spacing along the curb form. Too great a spacing between clamps will result in a wavy form line. Clamps and spacer plates should always be paired together. Failure to observe this will result in varying width curb.

Tamping should be even. The tendency is to tamp excessively between clamps, where it is easy, and to slight it next to the spacer plates, where it is most needed.

A true grade is an important consideration in gutter construction. Sight along the chalk line by which the forms are set to see that there are no sags between stakes and that no errors have been made in setting the line. After the forms are in place, sight over them and also look at them from across the street,

Close inspection is necessary when integral rolled curb is formed by hand.

with your head as nearly on a level with them as possible, to detect errors in grade.

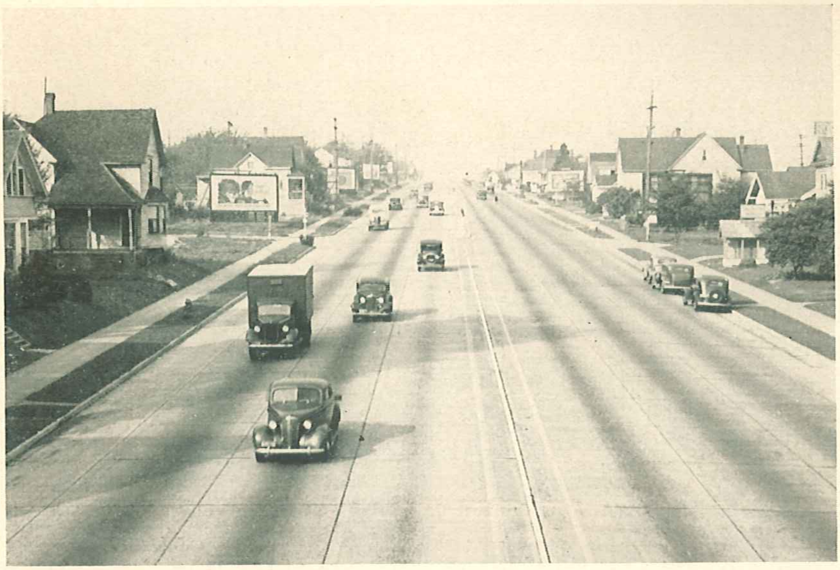
The circular curbs, or returns, at intersections need special attention. Straight and circular curbs should meet smoothly. The curved sections should neither bulge beyond the curb line nor depart from it so abruptly that an angle is formed.

If there is a gutter at the return, check the gutter forms visually for grade before concrete is placed. When the concrete will bear the weight of a carpenter's level, set one in the flow line of the gutter and see that it slopes in the proper direction. Have any errors in grade corrected at once.

Proper elevation is the important consideration for gutter forms since a slight depression may make a pocket in which water will stand after every rain and where dirt will be deposited.

Joints in the pavement slab should be continuous through curb and gutter. This is extremely important when curb and gutter are doweled to the pavement, and if not observed the curb and gutter will be cracked and spalled by movement of the slab. Some contractors prefer to construct the curb and gutter before paving. When such a procedure is followed, particular attention must be given the placing of joints to see that they are in line with planned paving joints.

Concrete with a slump of 2 to 3 in. is satisfactory. If the slump is too great, difficulty will be encountered in maintaining a straight curb face as the forms may bulge between clamps. Also, curb face forms must be left in place longer to prevent the curb from slumping down. If the slump is too little, honeycomb and finishing difficulties may result. The ideal consistency is the lowest slump with which concrete can be placed with minimum manipulation and yet result in no honeycomb.



Close attention to all details is required to obtain a smooth-riding, quick-draining, wide city pavement.

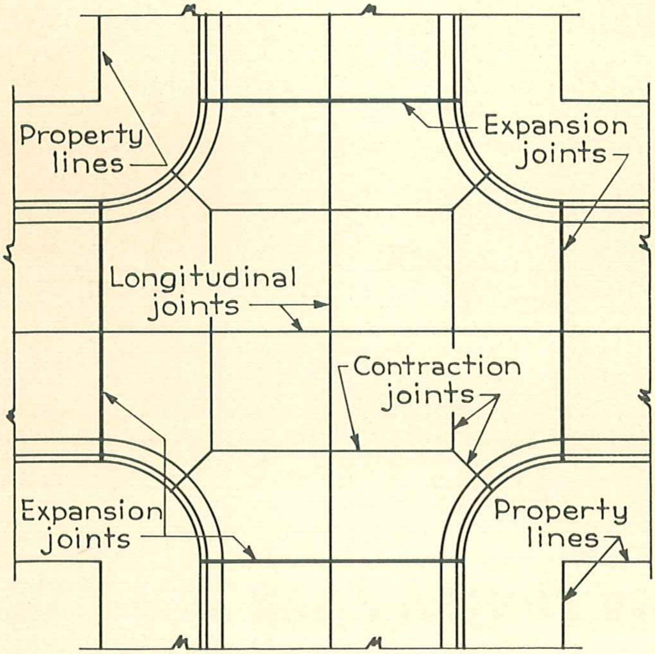
CITY PAVEMENTS

ONE of the important details which a street paving inspector must oversee is the layout of complicated street intersections. The plans should be followed insofar as they give the details, but under the best of conditions it will undoubtedly be necessary to make at least minor changes on the job. When it comes to intersection layout, the final check of the work should be with a good eye, a chalk line and a knowledge of the requirements of a good intersection.

A plat of every intersection should be in the inspector's notebook. One inch to 10 feet is a convenient scale. On this plat, points should be located at which stakes can be conveniently set. The elevation of the pavement at these points should be figured so that there is a slope of at least 1/8 in. per ft. in some direction, preferably toward the nearest gutter, and so that the different grades of the intersecting streets meet smoothly. The points should not be more than 10 ft. apart.

When intersections are drained by catch basins at the corners, the grade points can be located on the center lines of streets and on arcs of circles concentric with the curb returns. These grades are given by stakes set by instrument.

When the rough grading is completed, the intersection should be inspected. Any changes in contour which seem advisable should then be made and recorded on the notebook plat so that grade stakes for the pavement will be correctly set. No rules for laying out intersections can equal visual inspection in getting a well-balanced grade, but trusting entirely to the eye, without care-



This joint layout simplifies construction and has proved to be entirely adequate.

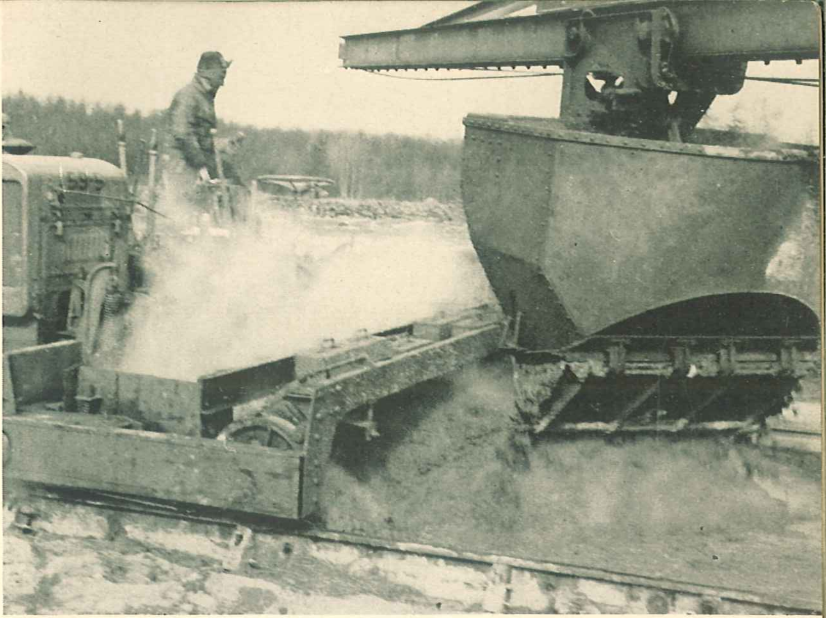
fully figuring grades, will result in a botched job. No part of an intersection should be paved until every square foot of the subgrade has been brought to finished grade. When water is carried across an intersection in valley gutters, the "through" street may be struck off with the templet used between intersections.

In right angle intersections the joint arrangement should be similar to that shown on the above sketch. Contraction joints should cross intersecting streets on the extension of the curb lines, or in line with the outside edge of gutter aprons. Expansion joints should cross streets at the ends of the curved portions of the curbs. Avoid acute angles at intersection of joints.

The circular curb at intersections should be given as large a radius as possible without cutting down the sidewalk space or encroaching too much upon the parking strip. The narrower the street the broader the returns should be to prevent collision between vehicles making the turn and others passing along the street. A good general rule is to make the straight and circular curb meet at the point where they intersect the property line extended.

After the requirements of the job under construction have been satisfied, excess earth should be disposed of as the street commissioner directs. Enough earth should always be left in the parking strip to form a berm against the back of the curb. This berm should be as high as the curb—at least a foot wide on top—and should be placed as soon as the curb has hardened. When the curb is built on a fill, earth must be hauled to make this berm.

The inspector should see that an expansion joint at least 1 in. wide is placed between the ends of crosswalks and the back of adjacent curbs. If no provision for expansion is made the walk will push against the curb and may break it off.



Heating the aggregates and mixing water is necessary when paving during severe weather.

COLD WEATHER CONSTRUCTION

FIRST consideration in cold weather construction is the subgrade. No pavement should be placed on a frozen subgrade. Straw is very effective in keeping frost from penetrating the grade. A subgrade which is not frozen too deep can often be thawed by burning gasoline on it. If this method is used care must be exercised to protect adjoining property.

Heat hastens and cold delays the hardening of concrete. As the temperature decreases, the rate of hardening is retarded until at the freezing point it ceases entirely. Therefore, when it is necessary to place concrete in freezing weather, or when the temperature is likely to fall below 35 deg. F. before the slab has hardened, precautions must be taken to insure protection of the concrete during the early curing period.

It is of vital importance that the temperature of the concrete be maintained as much above 50 deg. F. as possible for at least 5 days so that it may attain the required strength. A covering of canvas or tar paper with a thick layer of hay or straw will help to guard against freezing. Stable manure should never be used as a protective covering as it will cause permanent staining on the surface and ammonia may form which is likely to cause pitting and scaling.

The safest practice is to protect the concrete before it has had time to freeze. Concrete which has been frozen will seldom attain its full strength. Repeated freezing and thawing of newly laid concrete usually necessitates the removal of the frozen section.

It is necessary in severe weather to heat the aggregates and mixing water so that the concrete will have a temperature not lower than 70 deg. F. when placed. Then cover the slab so that as much as possible of the original warmth will be retained. The temperature of the concrete when placed should not exceed 100 deg. F.

In general, the use of so-called antifreezing mixtures should be avoided. Many of them contain chemicals which are known to be detrimental to the

A thick layer of straw or hay should be spread over the curing blankets to protect the concrete during the curing period.

strength and durability of concrete. Common salt should not be used. The addition of 5 per cent salt to the mixing water reduces the freezing point only 6 deg., but decreases the strength of the resulting concrete more than 30 per cent.

Within certain limitations calcium chloride may be used in portland cement mixtures to hasten hardening and to increase early strengths. The amount of the admixture should not exceed two pounds per sack of cement as larger amounts may decrease the strength. The admixture should be dissolved in the water before placing in the mixer.

The following convenient field method of adding calcium chloride to the concrete may be useful. Secure a 50 gal. drum and fill it about two-thirds full of water. Then add two 100-lb. bags of calcium chloride and stir until there seems to be no further dissolving of the crystals. The amount of calcium chloride which may be dissolved in water depends on the water temperature but, fortunately, this variation is not important as long as the water temperature is below 70 deg. F. One quart of this mixture per bag of cement used is equal to approximately one per cent calcium chloride by weight of cement. That is, if it is desired to add two per cent calcium chloride to a 6-bag batch of concrete, 3 gal. of the mixture should be added and the normal mixing water decreased by the same amount. As the solution is taken from the drum more water should be added and continually stirred. Maintain a concentrated solution by adding calcium chloride often enough so that undissolved crystals are always present on the bottom of the drum.

When these compounds are used in cold weather, they should not be used as a substitute for heating the materials and furnishing proper protection and heat to the finished structure, but only as an added precaution and as a means of shortening the curing period.

It must be remembered that no matter what method is used to accelerate hardening and obtain high early strength, the hardening will not take place with the desired rapidity unless the temperature is maintained at about 70 deg. F. It must also be remembered that the surface of the pavement must remain sufficiently moist during the period of curing to prevent checking and insure a tough, dense surface. If any lack of moisture is noticed, the surface should be sprinkled at intervals during the curing period.

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